Chapter 21
Ion Exchange (Liquid/Vapor) and Resin Adsorption (Liquid/Vapor)

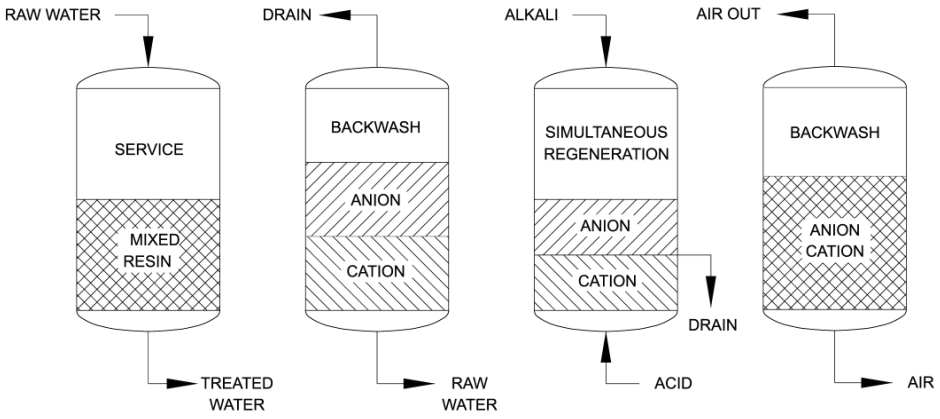
21-1. General

The processes of ion exchange and resin adsorption are described in the chapter's first section. The second portion of the chapter is a hazard analysis with controls and control points listed.

21-2. Technology Description

a. Ion Exchange.

Ion exchange technology uses nonconductive resins (solid or semi-solid organic materials) or polymers with reversibly reactive side groups to remove ions such as heavy metals from liquid or gaseous streams. The removal occurs by exchange of cations or anions between the contaminated water/gas and the resin or polymer, and their difference in bonding potentials. In practice, gaseous streams are usually treated using wet ion exchange resin. The gaseous ions are dissolved in the water, after which the ion can interact with the resin for the exchange. In general, larger metal ions, such as copper, lead, and calcium, will bind more tightly to the resin than smaller, lighter metals, such as sodium or potassium. Therefore, ion exchange resins utilize this characteristic by containing exchangeable sodium or potassium functional groups. Resins can be regenerated for reuse using acids or bases, or strong solutions that contain the weaker binding ions. During the regeneration process, the waste solution containing the concentrated target ions can then be properly disposed of. Figure 21-1 illustrates both ion exchange (liquid/vapor) and resin adsorption (liquid/vapor).



PRINCIPLE OF MIXED-BED ION EXCHANGE: (A) SERVICE PERIOD. (B) BACKWASH PERIOD. (C) SIMULTANEOUS REGENERATION. (ILLINOIS WATER TREATMENT CO.)

SOURCE: *CHEMICAL ENGINEER'S HANDBOOK*, PERRY & CHILTON (5TH. EDITION)

FIGURE 21-1. ION EXCHANGE/RESIN ADSORPTION

b. Resin Adsorption.

Resin adsorption removes undesirable ions from water on the same chemical basis as ion exchange except that the resin is not exchanged with another metal ion such as sodium or potassium, but is exchanged with the proton or hydroxyl group. Elution of the heavy metals with an acid or base regenerates the resin by reversing the exchange.

21-3. Hazard Analysis

Principal unique hazards associated with ion exchange (liquid/vapor)/resin adsorption (liquid/vapor), methods for control, and control points are described below

a. Physical Hazards.

(1) *Electrocution*.
Description. Workers may be exposed to electrical hazards when working around resin beds. If permanent or temporary electrical equipment is not ground-fault protected or grounded, especially in wet or damp conditions, an electrocution hazard exists.

Control. Controls for electrocution include:

- Verify that drawings include hazardous area classifications as defined in NFPA 70, Chapter 5, sections 500.1 through 500.10.
- Use controls, wiring, and equipment with adequate ground-fault protection in accordance with EM 385-1-1, "Safety and Health Requirements Manual," Section 11.G, NFPA 70, and UFGS 16415A, "Electrical Work, Interior," for the identified hazard areas.
- Perform all electrical work in accordance with codes and under the supervision of a state licensed master electrician.
- Never use ungrounded, temporary wiring during minor maintenance work on the units, or temporary wiring in wet or damp environments that is not approved for these conditions.
- Train workers in potential electrical hazards.

CONTROL POINT: Design, Construction, Operations, Maintenance

(2) *Liquid Transfer Equipment Design*.
Description. Improperly selected construction materials, such as untreated steel, can corrode or dissolve to a point of failure and cause damage to the facilities or expose workers to hazards associated with falling or collapsing equipment.

Control. Controls for liquid transfer equipment include:

- Use liquid transfer equipment (pumps, fan, blowers, piping, pipe fittings, valves, and instruments) fabricated from materials that are chemically inert to the liquid streams and contaminants.
- Install spill or leak detection instrumentation if warranted.

- Install drip pans or receivers at mechanical junctions throughout the transfer system.
- Consult EM 1110-1-4008, "Liquid Process Piping," and UFGS 15200A, "Liquid Process Piping," for appropriate pumping materials. Include in the design containment drip pans or receivers for potential leaks and spills.

CONTROL POINT: Design, Construction, Maintenance

(3) *Pressurized System Failure*.
Description. Ion exchange systems utilize pressurized beds (e.g., tanks, pumps, and piping). These can leak or fail, causing exposure to the contaminated influent stream or reconditioning solutions.

Control. Controls for pressurized system failure include:
- Design tanks and piping for the maximum operating pressure expected.
- Perform a Process Hazard Analysis (PHA) prior to startup and correct all deficiencies found.
- Hydro test all systems in accordance with UFGS 11250A, "Water Softeners, Cation-Exchange (Sodium Cycle)," before the system begins treatment operation.
- Train operators on standard procedures for pressurized systems, potential system failures, and necessary corrective action that would be required.
- Include containment drip pans or receivers where leaks may occur.
- Prevent chemical mixing.
- Install spill leak detection instruments if necessary.
- Implement routine system and operating inspections.
- Train operators in emergency procedures including life saving first aid, halting chemical reactions, extracting, decontaminating and stabilizing victims, and in emergency system isolation and shutdown procedures.
- Locate emergency eyewashes and showers at critical points throughout the system. (See American National Standards Institute ANSI Z358.1 – 1998.)

CONTROL POINT: Design, Construction, Operations

(4) *Backwash System Failure*.
Description. Some systems have automatic backwash resin regeneration cycles that utilize acidic or basic wash solutions. System failure may expose workers to physical hazards associated with the disruption and concentrated process chemicals.

Control. Controls for backwash system failure include:
- Design redundant automatic backwash failure controls and alarms to shut down the system as needed.
- Train workers in acid/base exposure hazards and controls (see 29 CFR 1910.1200).
- Provide emergency eyewash and shower at locations near areas of potential exposure. See ANSI Z358.1-1998.

- Provide appropriate personal protective equipment stations near potential failure points in the system.
- Train operators in emergency procedures including life saving first aid, halting chemical reactions, extracting, decontaminating and stabilizing victims, and emergency system isolation and shutdown procedures.

CONTROL POINT: Design, Operations, Maintenance

(5) *Fire or Explosion (VOCs).*
Description. Workers may be exposed to a fire or explosion hazard if, during regeneration of the resin, the heat of the reaction is sufficient to ignite VOCs that may have accumulated within the vessel.

Control. Controls for fire or explosion in vapor-phase systems include:
- Purge the vessel's atmosphere with inert gas prior to, or during, the regeneration to prevent an explosion or fire.
- Install temperature/pressure alarms within the system to warn of sudden or abnormal temperature/pressure changes indicating a potential system failure.
- Perform a Process Hazard Analysis (PHA) prior to startup and correct deficiencies found.
- Train operators in emergency procedures including life saving first aid, halting chemical reactions, extracting, decontaminating and stabilizing victims, and emergency system isolation and shutdown procedures.
- Locate emergency eyewashes and showers at critical points throughout the system. (See ANSI Z358.1 – 1998.)

CONTROL POINT: Design, Operations, Maintenance

(6) *Explosion.*
Description. Workers may be exposed to an explosion hazard during the mixing of incompatible chemicals. The resulting reaction may generate heat and pressure buildup causing an explosion.

Control. Controls for explosion include:
- Design the system to shut down during over-pressurization. In addition, install emergency warning alarms and pressure-relief valves or vents that discharge away from work areas.
- Include temperature/pressure alarms within the reaction vessels to warn of abnormal or sudden temperature/pressure changes that may indicate potential system failure.
- Train operators in emergency procedures including life saving first aid, halting chemical reactions, extracting, decontaminating and stabilizing victims, and emergency system isolation and shutdown procedures.
- Locate emergency eyewashes and showers at critical points throughout the system. (See ANSI Z358.1 – 1998.)

CONTROL POINT: Design

(7) *Treatment Buildings*.
Description. Permanent or semi-permanent treatment buildings may present life safety hazards such as inadequate egress, fire suppression systems, or emergency lighting systems.

Control. Controls for treatment buildings include:
- Meet the following construction requirements for permanent and semi-permanent treatment buildings: ANSI 58.1, "Minimum Design Loads for Buildings and other Structures," the "National Fire Code," the "National Standard Plumbing Code," "Life Safety Code," and the "Uniform Building Code."
- Design structures in compliance with either Air Force Manuals for those located on Air Force bases, USACE Technical Manuals at Army installations, or local building codes at Superfund, BRAC, or FUDS sites.

CONTROL POINT: Design, Operations

(8) *Emergency Wash Equipment*.
Description. Emergency shower/eyewash equipment required per 19 CFR 1910.151 is not always provided with adequate floor drains, thereby creating potential electrical hazards with ponding water, or walking surface hazards during required testing and use.

Control. A control for emergency wash equipment includes:
- See American National Standards Institute ANSI Z 358.1 – 1998: "Emergency Eyewash and Shower Equipment" for design requirements.
- Equip showers/eyewash equipment with accompanying functional drains to isolate and collect the shower/eyewash waters.

CONTROL POINT: Design

(9) *Fire (Flammable Materials).*
Description. Ion exchange resins are generally fabricated from flammable materials that can be ignited under certain operating and storage conditions.

Control. Controls for fire include:
- Consult and adhere to the appropriate resin Material Safety Data Sheets (MSDS) and the manufacturers' recommendations for proper use and storage.
- Train operators in flammability characteristics of resins used and operating conditions that are likely to produce flash point temperatures.
- Include critical temperature alarms to allow rapid cool down or shut down of the system.

CONTROL POINT: Design, Construction, Operations

(10) *Design Field Activities.*

Description. Design field activities associated with subsequent construction of the ion exchange system may include surveying, biological, soil gas, and geophysical surveys, trenching, drilling, stockpiling, contaminated groundwater sampling, and other activities. Each of these activities may expose personnel to physical, chemical, radiological, and biological hazards.

Control. Controls for hazards resulting from design field activities include:

- Prepare an activity hazard analysis for design field survey activities. EM 385-1-1, Section 1, provides guidance on developing an activity hazard analysis.
- Train workers in hazards identified.

CONTROL POINT: Design

b. Chemical Hazards.

(1) *Deteriorating or Incompatible Chemicals*.
Description. Resins (solid or semi-solid organic materials) used in ion exchange treatment technologies may have specific storage requirements regarding heat and moisture content, ambient temperature or relative humidity, and may deteriorate, producing potentially hazardous conditions (such as acidic conditions). Acids (sulfuric and hydrochloric) and bases (such as sodium hydroxide) used during regeneration processes are incompatible with each other and must be stored physically separate in the containment area. Inadvertent mixing may generate toxic fumes or cause fires.

Control. Controls for deteriorating or incompatible chemicals include:

- Store resins and acids or bases according to NFPA, manufacturers, and MSDS requirements.
- Do not store more resin than can be used within the acceptable storage period.
- Store incompatible materials, such as acids and caustics, separately or in individual secondary containment.
- Design storage systems based on incompatibilities using known process chemistry and MSDS information. Design facilities that keep incompatible chemicals isolated from each other.
- Equip each chemical storage tank or drum with adequate spill containment.
- Install spill or leak detection instruments as required.
- Require proper loading and chemical handling procedures.
- Train operators in proper chemical handling and proper use of personal protective equipment (PPE).
- Locate, install, and maintain emergency fire fighting equipment and eyewash and emergency showers at critical points throughout the system. (See ANSI Z 358.1 – 1998.)

CONTROL POINT: Design, Operations, Maintenance

(2) *Chemical Reagent and Resin Handling*.
Description. Workers may be exposed via the inhalation/ingestion/dermal exposure routes when adding chemical reagents and resins to the system. The chemical reagents may include sulfuric and hydrochloric acid. This activity may occur either at the initial loading of the materials or during the regeneration stage. The resulting exposure may cause burns, irritation, or more severe tissue damage.

Control. Controls for reagent and resin handling include:
- Handle chemical reagents and resins under ventilated conditions.
- Utilize secondary containment units for bulk quantities of hazardous chemicals where possible.
- Use appropriate PPE, such as an air-purifying respirator with acid gas cartridges and butyl rubber gloves.
- Locate an eye wash/chemical spill shower near chemical handling areas. (See ANSI Z 358.1 – 1998.)
- Train workers in potential chemical exposures to expect and the associated controls (see 29 CFR 1910.1200).

CONTROL POINT: Design, Operations, Maintenance

(3) *Backwash Fluid Solution.*
Description. The eluted acidic or alkaline solution from resin regeneration process contains heavy metals.

Control. A control for backwash fluid solution includes:
- Handle the backwash fluid solution with the same procedures and protocols as those used for process fluids (e.g., proper containment precautions and observing all personal safety measures when handling the fluid material).
- Locate and install and maintain emergency eyewash and showers at critical points within easy access to the resin bed. (See ANSI Z 358.1 – 1998.)
- Allow only trained, authorized operators to perform operation.

CONTROL POINT: Operations, Maintenance

c. Radiological Hazards.

(1) *Radioactive Contaminants*.
Description. Because the ion exchange treatment technology may remove radionuclides from aqueous waste solutions, the potential exists for worker exposure to radionuclides. In some geological settings, dissolved naturally occurring radioactive materials (NORM) or radioactive contaminants may be drawn up with the groundwater. Depending on the chemical form, the radioactive contaminant may be trapped by the ion exchange resin and concentrated to a point where a radiation hazard may develop.

Control. Controls for radioactive contaminants include:

- Test the contents of the waste stream.
- Determine the nature and extent of the radiation or radioactive materials if present.
- Consult a qualified health physicist to determine the exposure potential and any necessary engineering controls or PPE if radioactive material exceeds background levels.

CONTROL POINT: Maintenance

(2) *Radioactive Devices*

Description. Fire ands smoke detection devices, fluid level devices, and other process monitors and switches may contain radioactive devices potentially exposing workers through lack of identification or mishandling.

Control. Controls for inadvertent handling or exposure to radioactive devices include:

- Workers should be prevented from and warned against tampering with the devices.
- The location of the devices should be recorded so as to safely retrieve and dispose of them in case of a system failure and equipment replacement.

CONTROL POINT: Design, Operations and Maintenance

d. Biological Hazards.

Opportunistic Insects and Animals.

Description. For all sites, but especially in cooler climates, opportunistic insects or animals can nest in and around warm process equipment. Vermin, insect, and arthropod control measures should be considered in any design.

Control. Control of opportunistic insect and animals include:

- Electrical cabinets and other infrequently opened enclosures should be opened carefully and checked for black widow and brown recluse spiders, and evidence of rodents. As rodents can cause damage to electrical cables, all wiring should be inspected regularly.
- Ensure all storage is off the ground, palleted, and kept dry. Damp areas attract scorpions, rodents, and the snakes that eat them.
- Design ceiling corners and other high areas to discourage nesting by swallows, pigeons, and other birds. Birds are carriers of diseases, especially in their droppings, which can foul cranes and process equipment.

CONTROL POINT: Design, Operations and Maintenance